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Suvankar Ghosh

*Kent State University, sghosh1@kent.edu*

Alan Brandyberry

*Kent State University, abrandyb@kent.edu*

Marvin D. Troutt

*Kent State University, mtroutt@kent.edu*

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# Uncertainty and Enterprise Integration – A Real Options View

**Suvankar Ghosh**  
Kent State University  
sghosh1@kent.edu

**Alan Brandyberry**  
Kent State University  
abrandyb@kent.edu

**Marvin D. Troutt**  
Kent State University  
mtroutt@kent.edu

## ABSTRACT

Enterprise integration (EI) involves integrating business processes and data across organizations, systems, and applications and is a key spending priority for CIOs according to the consulting firm Gartner. Enterprise integration however represents an investment scenario fraught with a good deal of uncertainty on account of rapidly changing markets, technologies, and standards. EI represents a rich and dynamic market with ever-shifting boundaries, complex XML-based technology stacks, and a proliferation of standards. Complex and uncertain investment scenarios are best approached from the increasingly important real options (RO) valuation methodology. This paper develops a taxonomy of use cases of enterprise integration, assesses the uncertainty inherent in these use cases, and then develops decision-making heuristics based on the RO notion of Strategic Net Present Value (SNPV) for approaching investment decisions in EI.

## Keywords

Real Options, Strategic Net Present Value, Enterprise Integration, XML

## INTRODUCTION

RO has been steadily gaining recognition as the appropriate methodology for appraising investments under conditions of uncertainty. Graham and Harvey (2001) found in a survey of 392 CFOs that approximately 27% of this group is adopting real options analysis in capital budgeting. RO is being utilized in industries as diverse as bio-technology, manufacturing, and natural resources (Miller and Park, 2002). Erdogmus (2000) applies RO analysis to software development projects including developing Java application servers and bringing older software products in compliance with XML standards. RO has been used not just in correctly valuing software projects in the face of risk, but also in pro-actively controlling risk (Benaroch, 2002). Fichman (2004) argues for integrating the theories of IT innovation adoption with that of RO particularly with regard to investments in IT “platforms” and in environments characterized by high uncertainty and irreversibility of the investment decision. Fichman (2004) integrates theories and perspectives from strategy, organizational learning, innovation bandwagons, and technology adoption in assessing the value of the firm’s options in IT platform investment scenarios.

We approach a firm’s investments in enterprise integration (EI) technology from an RO perspective because EI is a strategic IT platform that integrates applications, systems, data, business processes, and organizations. Furthermore, as we demonstrate later in this article, EI investments are fraught with uncertainty in the technology, market, and standards for EI. Consequently, approaching EI investments from an RO perspective perfectly fits Fichman’s (2004) call for integrating the theories of technology adoption with that of RO for investments in IT platforms under conditions of high uncertainty. XML is the key technology underlying EI, hence, in this article, EI essentially refers to XML-based enterprise integration.

## RESEARCH METHODOLOGY AND THEORETICAL FRAMEWORK

The research in this paper is motivated by the need to approach investments in IT platforms such as EI under conditions of uncertainty from an RO perspective (Fichman 2004). However, this research does not follow the traditional quantitative positivistic paradigm that is seen in most IS research. Given Orlikowski and Baroudi’s (1991) classification of the epistemological underpinnings of IS research into the three main categories of positivism, interpretivism, and criticism, this

research falls in the interpretivistic category, with a hermeneutic approach utilized for the collection and analysis of the data. Hermeneutics (Ricoeur 1974, 1981) is based on an analysis of textual records pertinent to the phenomenon that exist in periodicals, journals, and these days of course also the Internet. Consequently, based on an analysis of available secondary information on the technology, standards, and market conditions pertinent to EI obtained from vendors' web sites, standards documents, articles published by users and consultants, we develop an uncertainty model for EI where uncertainty is characterized in terms of four principal factors: product architecture, market, and standards. Furthermore, we recognize that a strategic IT platform such as EI is used by the firm in several different ways ranging from data integration to process integration. Hence, we also develop a taxonomy of canonical use cases of EI and our analysis of uncertainty in the four principal factors is done at the more granular level of specific use cases of EI. After building our uncertainty model, we then develop managerial prescription as to what types of real options management should exercise under different conditions of uncertainty and capability of the firm to exploit EI technology.

In developing managerial prescription, we rely on the RO value construct of SNPV as the criterion for identifying preferred strategies. RO theory defines a new construct called the Strategic NPV which takes into account the value of managerial flexibility, or the value of the options available to management in any given investment program to change course as new conditions emerge (Trigeorgis, 2005; Trigeorgis and Mason, 1987; Park and Herath, 2000). Quite simply, Strategic NPV is defined as:

$$\text{Strategic NPV} = \text{Passive NPV} + \text{Value of Managerial Flexibility}$$

Here, the passive net present value (NPV) of an investment is the NPV that is obtained through traditional discounted cash flow (DCF) methods where a pre-committed investment program is assumed. In fact, what distinguishes RO from the traditional DCF accounting is that RO analysis is based on SNPV whereas traditional DCF ignores the value of managerial flexibility. Consequently, the managerial prescription developed in this article is based on an imputation of the likely SNPV of different real options strategies. For example, under conditions of high uncertainty and low firm capability to exploit EI technology, it is likely that the following relationship will hold between the alternatives of making an investment as compared to simply deferring the investment.

$$SNPV_{\text{defer option}} > SNPV_{\text{investment}}$$

Consequently, under such conditions the recommendation is to exercise the defer option. In general, the overall conceptual goal of the analysis in this article is to:

$$\begin{aligned} & \underset{s \in S}{\text{Max}}\{SNPV\} \\ & \text{subject to} \\ & \text{uncertainty} = U \in \{High, Low\} \\ & \text{capability} = C \in \{High, Low\} \\ & S = \{ \text{set of real options available} \} \end{aligned}$$

In other words, for given conditions of firm capability and uncertainty, the goal is find the preferred real options strategy that maximizes SNPV. However, we are not formally solving a mathematical programming problem in this article. Instead, we argue based on our interpretive hermeneutic analysis that certain real options strategies are likely to be preferred under given conditions of uncertainty and firm capability.

## USE CASES OF ENTERPRISE INTEGRATION

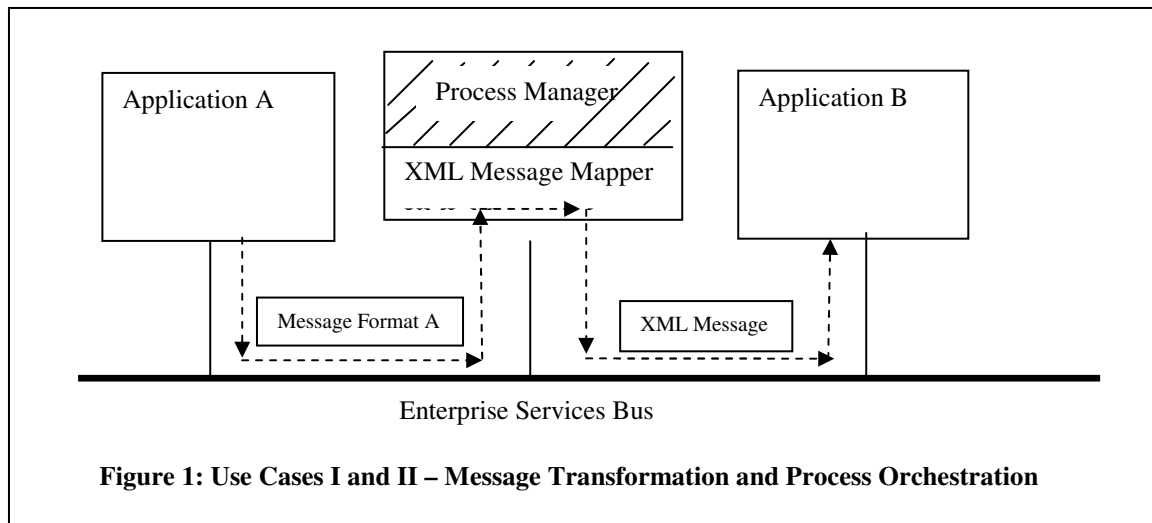
XML-based EI solutions are used to enable both data and process integration in the enterprise. We classify the use of EI technology by the enterprise in terms of the following four cases:

### I. Message transformation

- II. Process orchestration
- III. Data storage and retrieval
- IV. Heterogeneous information integration

Message transformation involves mapping messages from one format to one another, such as from a proprietary format to XML to achieve integration across applications, systems, and business organizations. In process orchestration, the XML transformation capability is augmented by a process orchestration function for managing and integrating business processes. Figure 1 shows the stand-alone message transformation and process orchestration use cases. The only difference between use cases I and II is that process mapping (shown as shaded in Figure 1) is present as an additional layer in use case II. The transformation of XML messages moving on a message transport infrastructure such as an Enterprise Services Bus (ESB) can be provided as a service on the ESB independently of whether process orchestration is done or not. Also, in this article, the term enterprise refers to the extended enterprise, so the scenario shown in Figure 1 could potentially include business-to-business integration (B2BI) flows as well, where an EDI message from another organization is transformed to an XML message before being sent on to an internal application.

Integration of traditional relational data stores with XML data is another major focus of enterprise integration. Currently, SQL relational databases are the dominant persistent data storage technology deployed. Consequently, supporting XML data implies that the capabilities of traditional relational data stores have to be enhanced in some fashion to handle the storage of XML data (Figure 2). The integration of XML data is necessary not only within the context of a single persistent store but also across multiple stores of structured, unstructured, and semi-structured data in a heterogeneous environment. This heterogeneous information integration scenario is the final major use case of enterprise integration technology. This scenario is referred to as enterprise information integration or EII. Figure 2 also shows the EII use case of information integration across a heterogeneous set of endpoints, which could include relational databases from different vendors, legacy applications, modern applications with Web Service interfaces, and XML documents and stores.

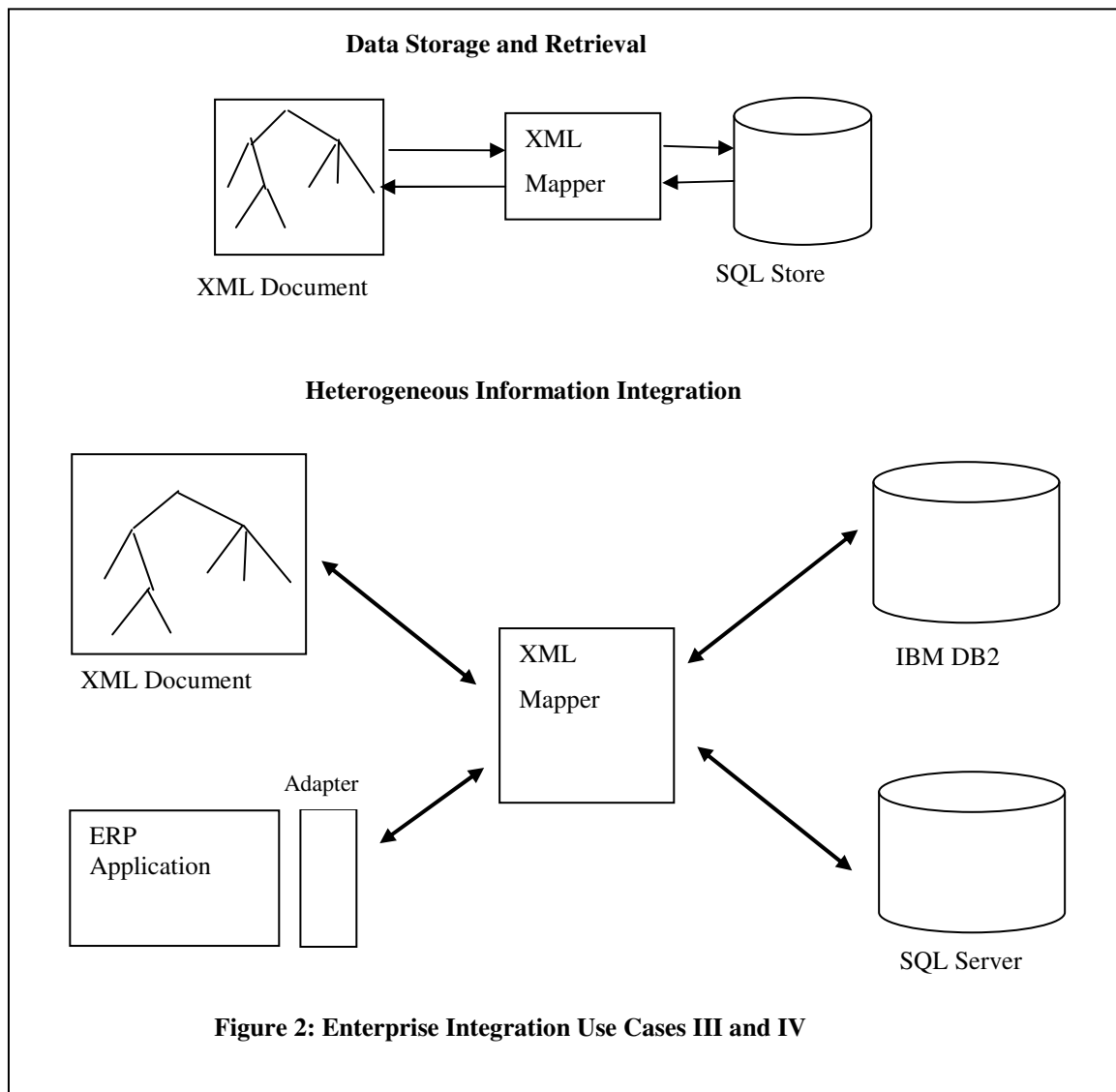


### AN UNCERTAINTY MODEL FOR EI

We ascribe the sources of uncertainty in the information frame of the decision-maker considering investing in XML-based EI solutions to the following four principal factors:

- Product Architecture
- Market
- Standards
- Performance

The uncertainty model for investment in enterprise integration is given in Figure 3 which shows the primary causes behind each of the four principal uncertainty factors. The product architecture-related sources of confusion and uncertainty have to do with the existence of multiple and sometimes conflicting architectures in the variety of integration products available. Market uncertainty is exacerbated by too many market segments with finely differentiated products that are also overlapping to a certain degree. Furthermore, it appears that there is a lack of directional clarity in some of these products with vendors sometimes trying to be all things to all people. Performance has always been a key customer criterion, yet there are few good vendor-independent studies of performance thus making performance claims somewhat questionable from the customer’s perspective. With newer product architectures, there is also the lack of a historical base of experience in performance optimization. The state of the standards has done much to confound matters further given the plethora of standards in the integration area, some of which are overlapping. The relative immaturity of some key standards gives both users and vendors pause before they can commit to them. These sources of uncertainty are, however, present to different extents in the four canonical use cases of EI technology, and we discuss these interactions next.



**Product Architecture**

The integration of the relational and XML-oriented worlds of data storage (use case III) demonstrates profound uncertainties in product architecture. Three basic approaches that have been debated over the last several years by the vendor and academic communities to storing XML data in a relational database are: 1) store the entire XML document as a character large object

(CLOB) or a binary large object (BLOB), 2) store it as a native XML data type, and 3) shred the document and store its contents in the database tables. Each approach has its pros and cons. Storing the XML document as a CLOB has the advantage of preserving all of the information in the original document. However, storing the document as a CLOB or a BLOB makes it opaque to transactions that need to update only parts of the document. Consequently, Kappel, Kapsammer and Retschitzegger (2004) in their review of techniques of mapping XML data to relational databases favor the shredding approach where there is a mapping schema to map the schema of the XML document to a relational schema for storing the data. Products such as Microsoft's SQL Server were among the first to have embraced the shredding model. Other vendors such as Oracle and IBM have moved quickly towards supporting a native XML data type in their relational databases, which Microsoft also does now. Finally, as opposed to hybrid storage models favored by the established relational database vendors, there is the camp of native XML database proponents with products such as Tamino. This discussion on the various solutions for the storage and retrieval of XML data illustrates the variety of architecturally different approaches to the problem. Therefore, for use case III, the level of uncertainty is deemed to be high relative to the product architecture factor.

## Market

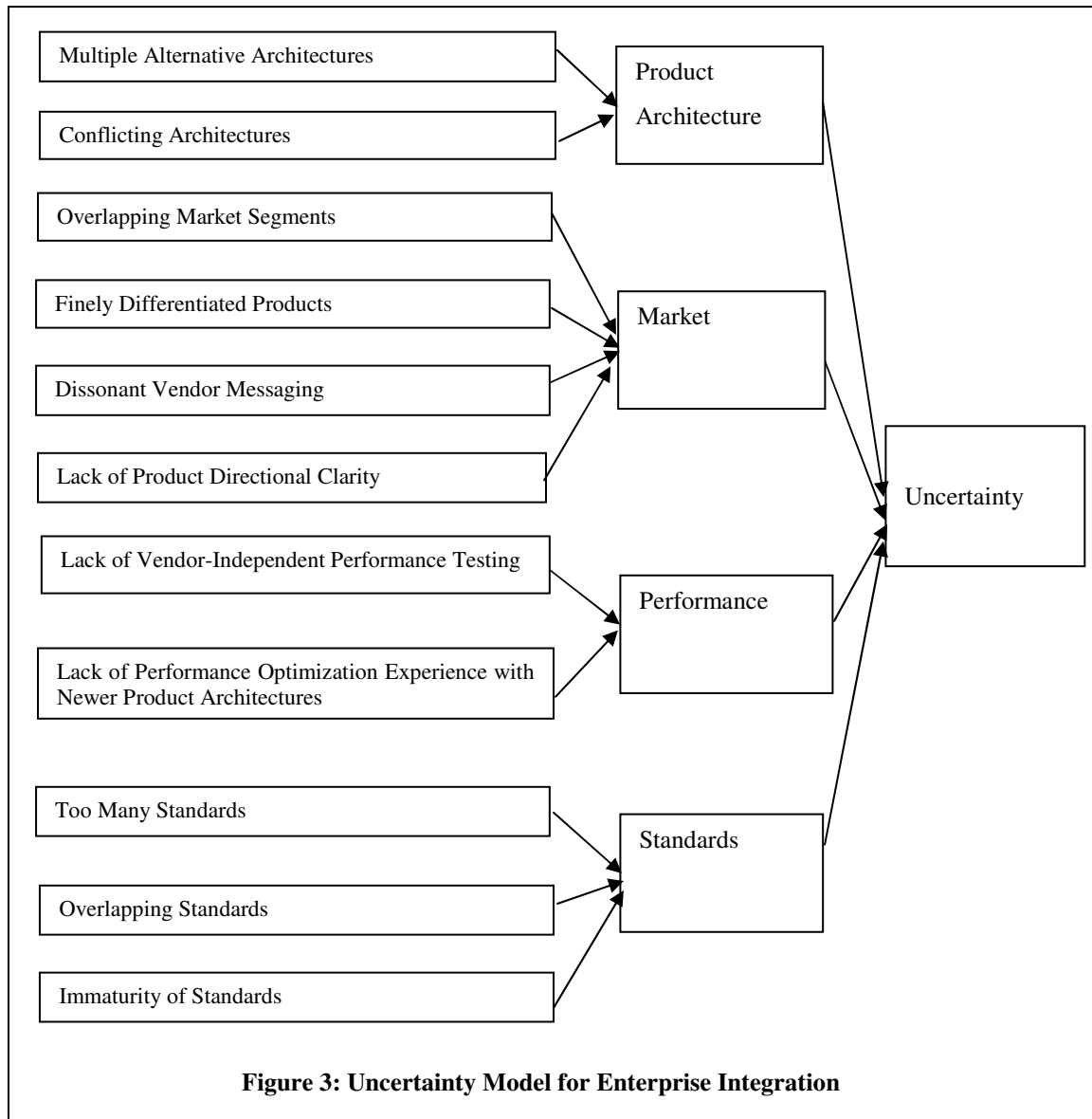
In the uncertainty model for EI shown in Figure 3, the antecedents to the principal factor that captures the market-related sources of uncertainty and complexity are overlapping market segments, finely differentiated products, dissonant vendor messaging, and lack of product directional clarity. EI actually encompasses the market segments of enterprise application integration (EAI), enterprise information integration (EII), and business process integration (BPI) and all of these sources of uncertainty are present in these three market segments. In our taxonomy of use cases, EAI, BPI and EII correspond to the use cases I, II, and IV. As Ghosh, Thornton, DeHondt and Faley (2007) point out, there is much confusion and overlap between the EAI, BPI and EII markets. The EII market grew out of products that were historically characterized as Extract, Transform, and Load (ETL) products for establishing data warehouses. Around the same time, vendors with federated database products also moved into the EII space. As opposed to the data integration-focused EII products, EAI and BPI were oriented towards process integration. However, with the advent of the real-time enterprise, the data integration and process integration worlds have borrowed heavily from each other, blurring the distinction between EAI, BPI, and EII. Today we have all of the following stripes of vendors competing in the enterprise integration space:

- EAI Suites – Suites provide a wide range of functionality including message brokering, data transformation, and process orchestration in a tightly integrated package.
- Enterprise Service Bus (ESB) – ESBs provide distributed message brokering and a services layer for implementing Service Oriented Architectures (SOA).
- Application Server – Application servers originally for building applications have now moved squarely into the integration space.
- Extract, Transform, and Load (ETL) – ETL products have broadened their focus from supporting data warehousing environments to also supporting integration particularly with capabilities for real-time movement and transformation of data.
- Enterprise Information Integrator (EII) – EII products use metadata management to provide a single enterprise-wide view of all data for building applications that are integrated from the ground up.
- Business Process Manager (BPM) – BPM engines foster integration by orchestrating business processes across organizations, systems, and applications.
- Business Activity Monitoring (BAM) – BAM is an entirely new product category that leverages the integration infrastructure to present the “real-time” state of the business on executive dashboards.

The enterprise integration market is very much in a state of flux and is one that is claimed by players of many stripes that are constantly redefining this market. Consequently, for the use cases I, II, and IV, the level of uncertainty associated with the market factor can be deemed to be high.

Even with regard to the data storage and retrieval use case, the database vendors have muddied the waters through their marketing which has caused a certain dissonance in the market. Although all the major relational database vendors have moved to support the new XDM-based XML data type, the extent of support is far from uniform across these products. Vendors have also played a “check off the box” game in this market where they can notionally claim support for every type of feature the market appears to want. However, behind this nominal support for a broad range of popular features, there is a dominant model that lies at the core of each vendor's product architecture and strategy, and which is its true strength. It is instructive to trace the historical path that the database vendors have taken in moving towards XML support as that signals the dominant model that the vendor espouses. The major database vendors such as Microsoft, Oracle, and IBM have taken different paths to their current state of support for XML with some having favored the shredding model initially whereas

others moved directly to supporting the XDM, though again with varying levels of support for the XDM and associated standards such as XQuery.



### Standards

Standards play an important role in any investment decision to deploy XML-based technologies. XML is all about standards. The problem is that in the area of EAI, BPI, and EII there are far too many standards that would reasonably tax any user organization's abilities to keep track of and evaluate. As an example, in the area of business process management itself, all of the following standards had been proposed at one time or the other by a medley of standards groups, consortiums, and vendors with market-moving power:

- Business Process Management Language (BPML)
- XLang
- Business Process Execution Language (BPEL)
- Web Services Flow Language (WSFL)
- WSCI (Web Services Choreography Interface)
- ebXML

- Business Process Schema Specification (BPSS)
- Business Process Execution Language for Web Services (BPEL4WS)

Furthermore, what often happens is that previously proposed standards don't go away, rather they are often subsumed under other standards as a matter of political expediency and compromise, which does nothing to lessen the informational complexity faced by users as they ponder standards in this space. Another troublesome problem with some key XML standards is that they sometimes overlap causing confusion regarding the role of these standards, the direction they are evolving in, and the appropriate positioning of products utilizing these standards. With regard to XML mapping, a core function in XML integration, XSLT and XQuery are the two key standards both of which can be applied to the problem of building a new XML document based on extracting information from one or more XML documents (Hoffman, 2005). Hoffman (2005) believes that both XSLT and XQuery will continue to coexist. While the preservation of both standards may indeed be justified as each has its own distinctive strengths, the overlap between XSLT and XQuery will continue to present a confounding picture to users. Moreover, as the XQuery standard is enhanced in future to include an update facility (XQuery Update Facility Requirements, 2005), it will have the capability to modify XML messages which would potentially deepen the overlap with XSLT. Consequently, with regard to the process orchestration and data storage and retrieval use cases, we assess the standards-related uncertainty to be high.

### Performance

There is a paucity of independent studies on the performance of key technologies and standards such as XSLT and XQuery. Many performance reports are either produced by the vendors themselves or groups affiliated with vendors. Such performance reports show a vendor's offerings in the best possible light in relation to its competitors. With most vendors producing such reports, this results in an environment of high information imperfection from the customer's perspective. Some good independent research has been done on performance from a theoretical perspective where the computational complexity of XQuery has been analyzed (Gottlob, Koch and Pichler, 2005). Gottlob et al. (2005) have studied the computational complexity of XPath 1.0 and find that the combined data and query complexity is in the Polynomial Time-Hard class of problems. They find that certain XPath constructs such as negation lead to this hardness. While this theoretical work does provide some interesting insights, we need more rigorous and vendor-unaffiliated research at the empirical level as well. It is worth reiterating that SQL query optimization techniques in the relational world have been analyzed and refined over many years. In contrast, the base of knowledge on optimizing the execution plan for XQuery calls is relatively meager. The relative immaturity of some of these integration technologies and the lack of true vendor-independent testing makes for an uncertain picture across the board as far as performance is concerned. Therefore, performance-related uncertainty is deemed to be high in all four use cases.

### Use Case-Uncertainty Mapping Matrix

The preceding discussion on the nature of the uncertainties in the decision context to invest in EI and the use cases where these uncertainties are high is captured in Table 1. The cells of high uncertainty mark special areas of concern; for example, the table shows that product architecture-related uncertainty is high in the storage and retrieval use case while market uncertainty is high in all the uses cases. It is the high value cells that contribute the most to the overall uncertainty in the investment decision and there are several such cells to make the overall picture of investing in EI an uncertain proposition indeed.

### IMPLICATIONS FOR MANAGEMENT

We have argued that the decision to invest in XML integration technologies is associated with an information context that is fraught with much complexity and uncertainty. It is precisely such decision-making contexts to which a real options approach is most suited. The real options frame best guides the normative evaluation of the balance between exploitation and exploration (Kogut and Kulatilaka, 2001). If traditional valuation approaches were to be applied to EI investments, they would likely favor quick exploitation since EI technology clearly does bring value to the enterprise. Looking at the same investments from a real options lens, however, would point to a more nuanced and cautious approach. The RO perspective encourages decision-makers to look at their alternatives by including an assessment of the value of managerial flexibility inherent in each alternative. Possible responses by management to the question of investing in EI range from simply deferring the investment decision to making a small exploratory investment to continuing a planned build-out of the integration infrastructure to a full and immediate exploitation of this technology. Our recommendation is that the real options view and the arguments regarding uncertainty be utilized by decision-makers as a conceptual framework in analyzing the decision to



		Principal Factors of Uncertainty			
		Product Architecture	Market	Standards	Performance
Enterprise Integration Use Cases	I. Message Transformation	Medium	High	Medium	High
	II. Process Orchestration	Medium	High	High	Medium
	III. Storage and Retrieval	High	High	Medium	High
	IV. Heterogeneous Information Integration	Medium	High	High	High

**Table 1: Extent of Principal Factor Uncertainty in Enterprise Integration Use Cases**

implement enterprise integration. The simple conscious recognition that deferring may have real intrinsic value is a positive step. Examples where firms have moved forward in very uncertain environments, often due to bandwagon effects associated with new technologies, are numerous and have often resulted in negative consequences for the organization. Although the advantages of deferring must be balanced with competitive pressures and any need to develop critical capabilities, the higher the uncertainty level, the more advantageous the decision to defer generally is. Exercising the defer option is typically tied to a schedule for revisiting the decision, such as annually, to assess if the uncertainties that caused the deferral in the first place have lifted to a certain extent. In other words, for organizations that are very new to XML-based EI and perceive a high level of uncertainty in this decision, the following is likely to be true when this decision is viewed from an RO lens:

$$SNPV_{defer\ option} > SNPV_{investment}$$

The level of maturity a firm has with EI is also an important factor. This “maturity level” could be analyzed utilizing the Capability Maturity Model (CMM) (Paulik, Weber, Curtis and Chrissis, 2003) which defines different levels of maturity of the organization with software processes, or by less formal methods. The effect of a low maturity-level is to amplify uncertainties in the environment which would tend to increase the value of implementation options that maximize managerial flexibility. These levels of implementation represent points on a continuum between complete deferral and complete implementation and would scale the advantages and disadvantages of both the defer and the full implementation options. With greater maturity, the organization could get progressively more aggressive with the next step being a small exploratory investment in XML-based EI. The recommendation for this exploratory step would be to build the integration infrastructure from the outside in, or from the periphery to the core, rather than from the inside out. This outside-in strategy could be implemented by merely engaging the XML capabilities of the hybrid relational and XML enterprise databases, which are part of the end-points of the integration infrastructure. Many of these enterprise databases have already been migrated to the latest versions, which have this hybrid support, for reasons other than XML. This strategy of building the integration infrastructure from the periphery avoids the large and immediate expense of deploying at the core an EAI suite – or its less costly but still expensive cousin, the ESB – and leverages sunk costs in the enterprise databases while preserving the firm’s options for the future. Therefore, for organizations in the early stages of progressing up the ladder of CMM maturity levels, the following is likely to be true for the RO measure of SNPV:

$$SNPV_{outside-in\ strategy} > SNPV_{EAI\ Suite\ or\ ESB\ strategy}$$

Companies with a greater level of maturity with XML-based EI may indeed directly opt for an EAI suite or an ESB-based strategy. From an RO perspective, ESB offers a higher value of managerial flexibility since services can later be layered on top of the ESB. Therefore, it is reasonable to expect that the following would be true for companies moderately experienced in XML-based EI and who also see sufficient value in preserving the flexibility of adding services to the ESB at a later stage:

$$SNPV_{ESB \text{ strategy}} > SNPV_{EAI \text{ Suite strategy}}$$

However, for companies at high levels of CMM maturity who understand XML-based EI very well and would like to deploy a comprehensive set of integration capabilities quickly to meet critical needs such as meeting a key customer's requirements for B2BI, the value of preserving managerial flexibility may not be high. The high level of organizational capability in XML-based EI is actually tantamount to controlling uncertainty and thus the SNPV maximization rule can be replaced by the traditional NPV rule. For such cases, the investment decision rule that is likely to apply is:

$$NPV_{EAI \text{ suite strategy}} > NPV_{ESB \text{ strategy}}$$

These decision-making heuristics regarding which investment strategy is preferred as a function of the environmental uncertainty and a firm's capabilities with the technology could be progressively expanded to encompass all the different categories of products identified in the Market section.

## CONCLUSION

This paper develops a framework from an RO perspective for making investment decisions in modern enterprise integration technology, which is typically XML-based. The use of EI by the firm is first defined in terms of a set of canonical use cases and then the uncertainty inherent in these use cases is analyzed. A set of decision-making rules or heuristics is then formulated that is based on the RO metric of Strategic Net Present Value that considers the value of managerial flexibility or the options available to management under different investment strategies. This RO-based framework is expected to be beneficial in informing management decision-making in the vital area of investments in enterprise integration, which is an area characterized by much technological, market, and standards uncertainty.

Finally, approaching investment decisions from a real options view represents a rather dramatic departure from the traditional discounted cash flow (DCF) valuation approaches that firms are familiar with. In recognition of the problem of the complexity behind options pricing models, there have been attempts made to make RO analysis more tractable by reducing it to a procedure that is akin to computing the net present value (NPV) of an investment. Feinstein and Lander (2002) show that if a properly weighted average of the risk-free rate and the NPV discount rate is used to discount future cash flows, then the RO and NPV models lead to equivalent results. Firms would do well to start building expertise in the real options methodology which represents perhaps the most significant advance in the areas of capital budgeting and corporate strategy in the last fifteen years.

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